variables. The I-395 overpass test area incorporated in the Seminary Road Test Site includes heavier vehicle traffic and multiple overpass levels and angles.

Acquisition of building sites and equipment installation in the I-395 overpass area is commencing as a result of the successful collection of the overpass benchmark data from the Crystal City overpass test site. The five buildings in the Seminary Road Test Range area which have been acquired are Sites A, B, C, E, and F shown in Figure A2-1. The equipment installations at these sites provided data on reception of the S-Band signals.

Equipment installation was composed of placement and erection of the Ku-Band to S-band transponder components on the Test Range building roof-tops and the connection of the equipment to an electrical source. The three major components related to the installation are: a 1.8 meter diameter Ku-Band receive antenna with LNB, mount, and counterweight; a transponder electronics box; and, an S-band transmit antenna with mounting mast and tripod. The elements of the experimental system mounted on the Test Range roof-tops are environmentally secure.

The 1.8 meter Ku-Band receive antenna is a standard parabolic dish made of spun aluminum. The mount for the antenna is made of steel. The antenna is supported by the mount on a three foot post and stabilized by three legs, each of which terminates with a platform. Each platform is counter-weighted with 320 lbs for a total of 960 lbs of ballast per Ku-Band antenna. The Ku-Band antenna mount incorporates adjustments for azimuth and elevation which are required in the final stage of installation. The Ku-Band receive antenna is placed on the building roof with a clear view to the southwest for the acquisition of the signal from the SBS-6 satellite. Figure A2-5 shows an assembled and counter-weighted Ku-Band antenna assembly.

Figure A2-5 Ku-Band Antenna Assembly

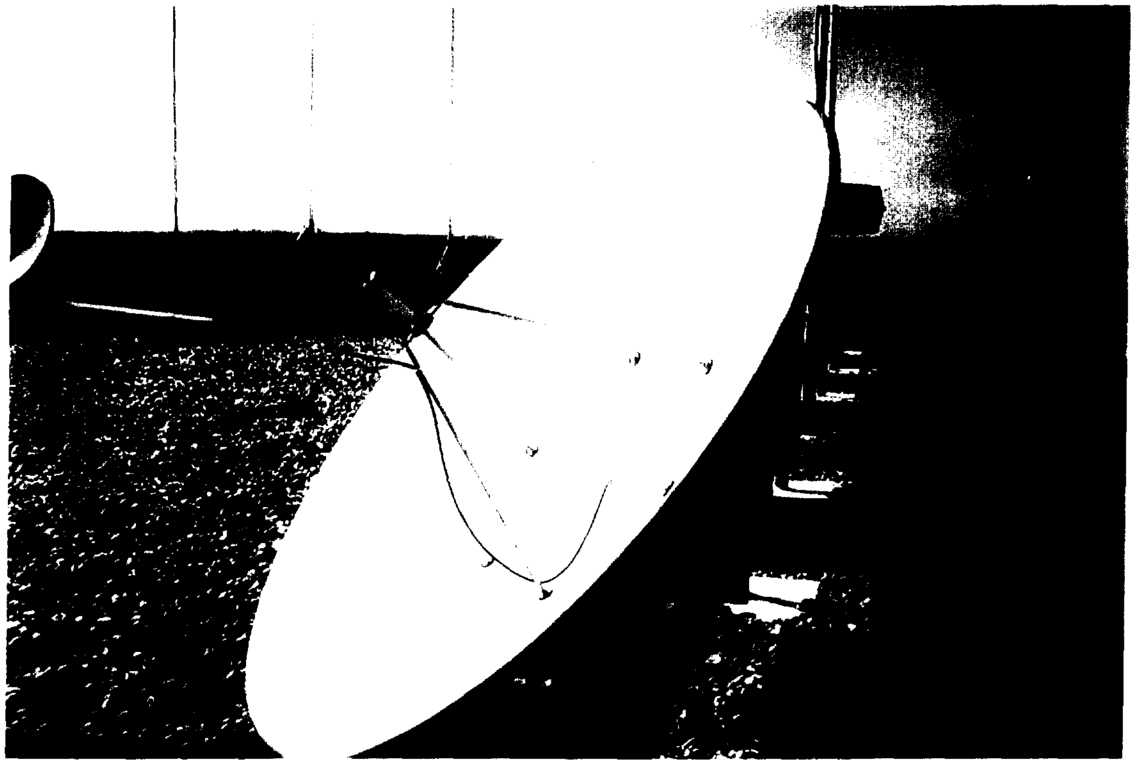


Figure A2-6 Transponder Electronics Assembly

The transponder electronics box is an environmental enclosure measuring approximately 2 feet square and 10 inches tall. Two sides of the transponder box are covered with heat sinks for the enclosed electronics. The other two sides of the transponder box have connections for the received Ku-Band signal, the transmitted S-band signal, 120 volt/20 amp electrical service, and ground for lightning protection. The electrical service is run from the building power supply to the box using approved outdoor methods and connections. The transponder box is placed in proximity to the rest of the equipment. No assembly is required for the transponder box except for the aforementioned connections. Figure A2-6 shows the transponder box.

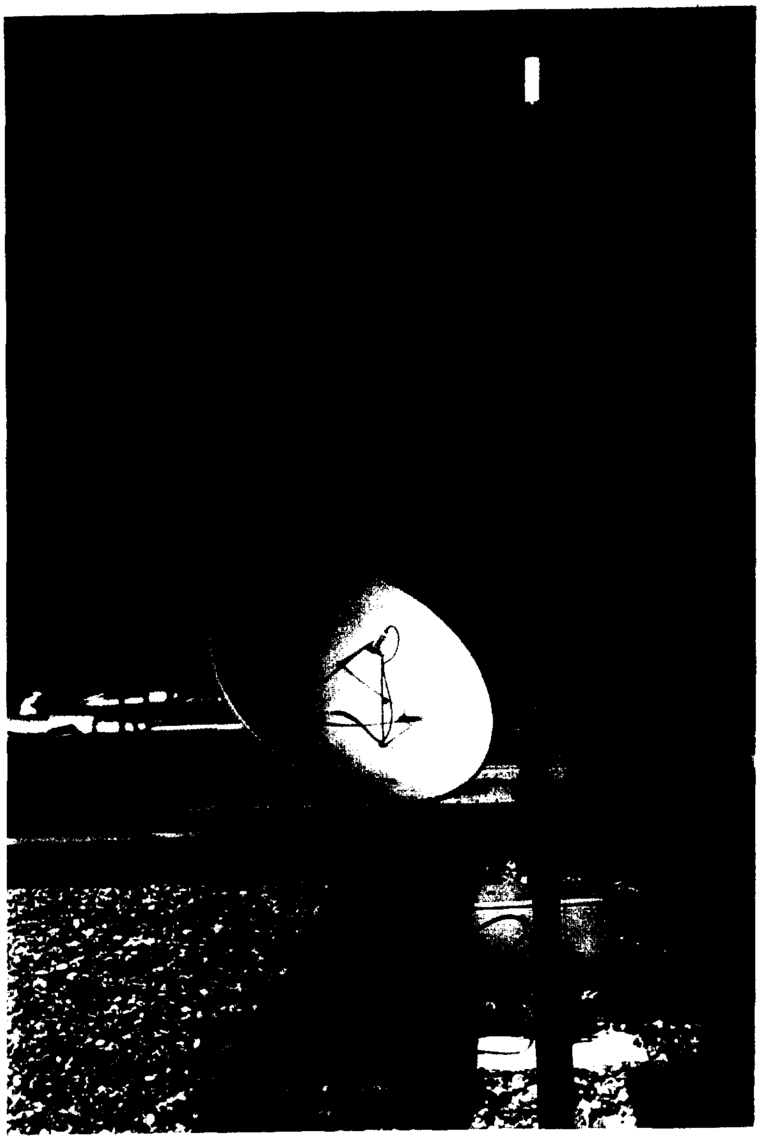
The S-band transmit antenna assembly is composed of three elements. The first element is the omni-directional S-band antenna and connector cable. The S-band antenna is a cylinder 2.5 inches in diameter and 6.5 inches in height. This antenna mounts to a 20 foot tall mast. The entire assembly is kept vertical by use of an antenna tripod weighted with 80 lbs of ballast on each leg for a total weight of 240 lbs. These three elements are assembled as a unit on the roof-top.

The Ku-band antenna LNB is connected to the transponder electronics box with RG-59 cable. The connection between the S-band transmit antenna and the transponder electronics box is via RG-8 cable. Cable runs are kept as short as possible to decrease losses to the received or transmitted signal.

The transponder electronics box is connected to 120 volt/20 amp grounded electrical service with weatherproof connectors. All of the equipment is grounded to a suitable earth ground for lightning protection. Figure 2A-7 shows a complete CD Radio experimental system transponder assembly incorporating all of the elements.

After assembly the Ku-band antenna is directionally peaked on the SBS-6 satellite, the receiver tuned to transponder 19A and the S-band transmit frequency is set. The S-band transmission pattern was verified against the predicted coverage area. Verification was performed in two steps. The first step in the coverage area verification was a check of the elevation

Figure A2-7 Rooftop Equipment, Installed on Site



angle from the mobile vehicle path to the S-band antennas on the roof-tops. This was accomplished by sighting the S-band antenna utilizing an inclinometer from the Test Range transit path. Elevation angles from the transit path were then compared to the predicted elevation angles from the Test Range design. The predicted results were achieved.

The second step in the coverage area verification incorporated the transmission of a continuous wave carrier from the CD Radio studio. This carrier was transmitted over SBS-6 and received by the roof-top transponder Ku-Band antenna. The carrier was then retransmitted at S-band by the mast mounted omni-directional antenna after conversion by the transponder. Each transponder retransmitted the carrier at a different frequency within the proposed S-band allocation for satellite DARS. The coverage area was verified by measuring the signal strength and continuity around the Test Range loop.

The experimental system mobile vehicle was used for data collection around the Test Range area. The test carrier was received through the experimental system mobile antenna. Since each transponder retransmitted the carrier at a different frequency, the signal reception data from the mobile vehicle could be correlated to a particular transponder site. The data was then compared to the Test Range design. The results were consistent with the design objectives.

APPENDIX A3.

TEST SYSTEM DESCRIPTION

A3.1 INTRODUCTION

CD Radio is implementing a satellite system capable of providing many channels of satellite DARS to cars or fixed receivers on an ubiquitous basis anywhere within the continental United States. The system is designed uniquely to mitigate both multipath fading and blockage by use of satellite spatial diversity in combination with radio frequency and time diversity. The system also employs a geometry wherein all mobile platforms have elevation angles to both of the diversity satellites greater than 20°. Since implementation of the satellite system will require three years, a demonstration has been performed using terrestrial facilities in order to allow evaluation of DAR service capabilities in advance of satellite system operations.

The CD Radio System consists of two geosynchronous satellites, one located over the east coast of the United States at 80° West Longitude, and the second over the west coast of the United States at 110° West Longitude. The satellites receive in the 6720 MHz band and transmit in two 8 MHz segments of the 2310-2360 MHz band. The satellites each receive the same transmission from the system's up-link/programming center essentially simultaneously and retransmit the signal through an antenna beam covering the continental United States. The retransmission frequencies of the two satellites are separated by 20 MHz and the beam edge EIRP is 57 dBW. The high EIRP is required due to the low gain of the mobile platform antenna. The transmission consists of 30 stereo CD music channels and a 128 kb/s service channel. The CD music channels are compressed prior to transmission using a joint encoding algorithm so only a 128 kb/s output data rate is required for each. The channels are digitally multiplexed together (i.e., TDM-time division multiplex) with interleaving in time, resulting in a 4 Mb/s output signal. The output signal is convolutionally encoded and then transmitted to the satellites using offset quadraphase shift keying (OQPSK).

The satellite retransmissions are received by the mobile platforms, particularly passenger automobiles. The mobile platform G/T at worst operational aspect angle is -19 dB/K. The antenna is designed to provide 3 dBi gain within a 20°-60° elevation angle range at all azimuths. The antenna is physically 2.5 cm in radius and 0.4 cm thick. After radio frequency reception, amplification and down conversion, the transmission from each satellite is individually demodulated and then de-multiplexed. The user selects the specific music channel desired which is then routed to the decompressor, the digital-to-analog converter and to the audio amplifier-loud speaker subsystem. The mobile platform receiver just described enjoys great resistance to multipath fading and blockage since its mechanization takes advantage of satellite spatial, frequency and time diversity.

It is difficult to demonstrate the capabilities of the just described DAR satellite system using terrestrial facilities to emulate the satellites. This is because achieving a 20° elevation angle to the mobile from the terrestrial transmitter emulating the satellite over a reasonably large area requires buildings or towers of great height. Also, the demonstration of spatial diversity requires two transmitters covering the same geographical area resulting in a large number of transmitters. A demonstration satellite system emulation range was constructed in Northern Virginia close to Washington D.C. Five high-rise building tops were used as transmit locations allowing a vehicle driving route of approximately 3.5 miles throughout which two transmit locations are at 10° or more elevation angle from the vehicle. The particular test driving route included areas representative of both urban and suburban environments as well as areas with trees and a superhighway overpass.

The 30 CD music channels and service channel were generated at a programming/up-link earth station in Washington, D.C. using the compression, multiplexing and modulation described earlier. The uplink station transmitted the signal at Ku band to the SBS-6 satellite which relayed the signal to standard VSATs on the high-rise building roofs. The VSAT received signal was translated by a stable frequency converter to a specific frequency within the 2310-2360 MHz band. The signal was then re-radiated using a small S-band transmitter and omni-directional antenna. The S-band EIRP was adjusted to equal that which would have been received at the mobile platforms from the previously described geosynchronous satellites. A standard passenger vehicle was used for the demonstration which was outfitted electronically with an operational satellite DARS receiving system. A small depression was made in the car roof, the antenna inserted and the roof area repainted. The automobile radio was modified with a button to select DAR in addition to AM and FM and an expanded display was used to show the music composition name and composer being played on the CD channel selected. The vehicle operator would drive the automobile route and listen to the CD music channel of choice.

A3.2 STUDIO

A radio studio environment was simulated by electronically generating twenty five (25) minutes of broadcast quality digital audio material reflecting planned narrowcast music formats. To this end, twenty five minutes for each of the thirty channels of program audio were first captured on Digital Audio Tape (DAT) prior to computer storage, compression and transmit preprocessing. All compression and processing is done in non-real time, prior to transmission. That is, the actual transmit signal used to modulate a OQPSK carrier is generated from the serial transmission of the pre-processed audio data in a computer file generated prior to transmission.

The source digital audio data was generated by direct digital recording from Compact Disc to DAT tape for each channel through a SPDIF serial digital audio link. The digital audio signal from the DAT for each channel was then played back and passed simultaneously through a Digital Integration Corporation Model SRC-1000 Universal Digital Audio Sample Rate Converter (to change the 44.1 Khz source CD sample rate to the 48 KHz required by the PAC encoding algorithm) and a Townshend Computer Tools DAT-LINK+Digital Audio Interface to a Sun Workstation SCSI bus. The Sun workstation then takes the SCSI data and stores it directly onto an external (SCSI) 1.8 GB Hard Disk.

Once the source material was captured into their respective 288 MByte files (48K*2 *1500*16 bps), these files were then individually processed by a PAC encoding program to generate their respective 24 MByte (128 Kbs * 1500 seconds) compressed audio data files which are then rate/size suitable for transmission.

The individual compressed audio data files are then used to generate a TDM byte interleaved multiplex data stream/file by a TDM multiplexing program. The basic TDM stream consists of 32 channels or time slots, each of 1 octet duration (i.e. a byte interleaved multiplex data stream). Each 32 octet block or frame is denoted as the primitive or P-Frame, as illustrated in Figure A3-1. Channel Slot 0 consists of the network control channel data and auxiliary program data, slots 1 to 30 consist of the program channel audio octets and the final slot 31 is reserved for the Time Interleaver Control and Synchronization information. In order to support the system frequency diversity and seamless switch-over requirement between carriers, it is necessary that the receivers for each carrier have enough memory to store and track data for the maximum time/phase delay encountered. To this end, the multiplex frame format is extended to include a multi-frame period of 256 P-Frames or 16 msec as illustrated.

Channel/Slot 0 of the P-Frame is denoted as the Network Control Channel (NCC). Part of it is allocated to synchronization, part to the program audio display data and the remaining is free for other network control tasks. Figure A3-2 illustrates the multi-frame multiplexing format that is used in the NCC. It could be noted here that total radio display requires a maximum of 96 ASCI characters (bytes). To account for this requirement, the 96 character radio "display" messages for each channel are transmitted in the NCC in blocks/packets of 98 bytes or octets. Since each channel is allocated 7 octets per multi-frame, therefore each channel display packet is distributed over 98/7=14 multiframes. Consequently, Byte #1 of the NCC data in each multi-frame was actually also used for display synchronization in that it contains a modulo-14 multi-frame count to denote the start of a radio channel control/display packet.

CD Radio
Source TDM Format

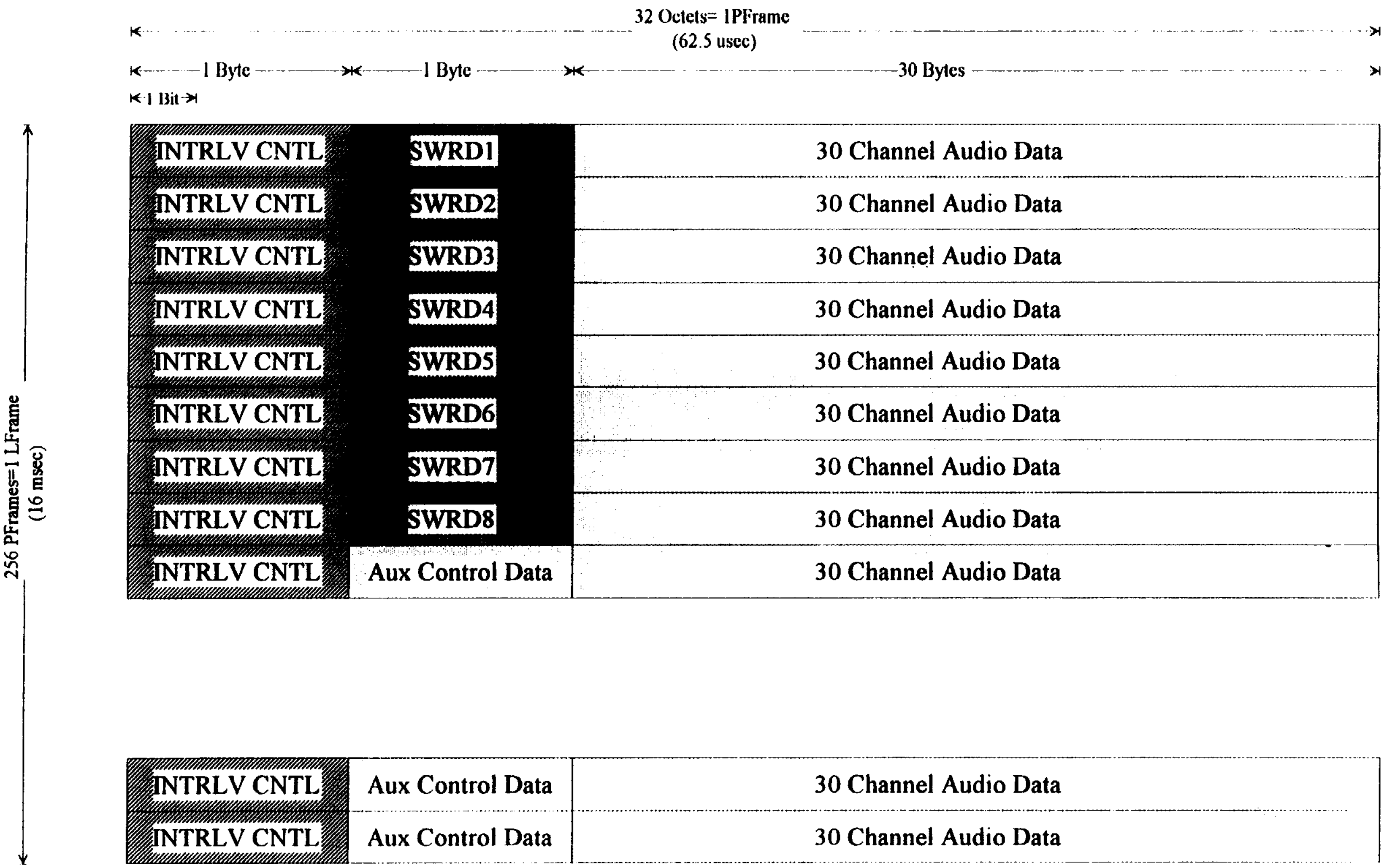


Figure A3-1 Signal Source TDM Format

CD Radio
Network ControlChannel Data
Multi-Frame Multiplexing

32 Octets from 32 PFrames
(2 msec)

256 PFrames=1 LFrame
(16 msec)

#1	#2	#3	#4	#5	#6	#7	#8	#9		#31	#32
SYNC WRD # 1	SYNC WRD # 2	SYNC WRD #31	SYNC WRD # 4	SYNC WRD # 5	SYNC WRD #6	SYNC WRD # 7	SYNC WRD # 8	NCD #1		NCD # 23	NDC # 24
NCD #25	CHNL1 BYTE #1	CHNL2 BYTE #1	CHNL3 BYTE #1	CHNL4 BYTE #1	CHNL5 BYTE #1	CHNL6 BYTE #1	CHNL7 BYTE #1	CHNL8 BYTE #1		CHNL30 BYTE #1	NCD #26
NCD #27	CHNL1 BYTE #2	CHNL2 BYTE #2	CHNL3 BYTE #2	CHNL4 BYTE #2	CHNL5 BYTE #2	CHNL6 BYTE #2	CHNL7 BYTE #2	CHNL8 BYTE #2		CHNL30 BYTE #2	NCD #28
NCD #29	CHNL1 BYTE #3	CHNL2 BYTE #3	CHNL3 BYTE #3	CHNL4 BYTE #3	CHNL5 BYTE #3	CHNL6 BYTE #3	CHNL7 BYTE #3	CHNL8 BYTE #3		CHNL30 BYTE #3	NCD #30
NCD #31	CHNL1 BYTE #4	CHNL2 BYTE #4	CHNL3 BYTE #4	CHNL4 BYTE #4	CHNL5 BYTE #4	CHNL6 BYTE #4	CHNL7 BYTE #4	CHNL8 BYTE #4	•••••	CHNL30 BYTE #4	NCD #32
NCD #33	CHNL1 BYTE #5	CHNL2 BYTE #5	CHNL3 BYTE #5	CHNL4 BYTE #5	CHNL5 BYTE #5	CHNL6 BYTE #5	CHNL7 BYTE #5	CHNL8 BYTE #5		CHNL30 BYTE #5	NCD #34
NCD #35	CHNL1 BYTE #6	CHNL2 BYTE #6	CHNL3 BYTE #6	CHNL4 BYTE #6	CHNL5 BYTE #6	CHNL6 BYTE #6	CHNL7 BYTE #6	CHNL8 BYTE #6		CHNL30 BYTE #6	NCD #36
NCD #37	CHNL1 BYTE #7	CHNL2 BYTE #7	CHNL3 BYTE #7	CHNL4 BYTE #7	CHNL5 BYTE #7	CHNL6 BYTE #7	CHNL7 BYTE #7	CHNL8 BYTE #7		CHNL30 BYTE #7	NCD #38

Figure A3-2 Multi-Frame Multiplexing Format

The multiplexing process consists of first assembling/building the NCC file and all 30 compressed audio channel files. The bytes/octets from these files were then sequentially accessed to form/build a single byte interleaved transmit baseband multiplexed signal/file of about 744 MB (31*24 MB). This file is then ready for the last stage of baseband signal processing.

The final processing steps consist of the line/symbol Encoding process and the Time Interleaving function. The encoding involves a standard rate 1/2, constraint length 7 FEC convolutional encoding. The time interleaving function is a ComStream proprietary implementation of a Ramsey Type II interleaver which spreads/scrambles the source data over a programmable interleave depth of up to 4 seconds. Based upon a worse case error correcting capability of 1 in 16, the interleaver should permit an error free burst correcting capability (i.e. maximum fade duration) of up to 250 msec. It should be noted that the FEC encoding is necessarily done before the interleave process and the Interleave control data is necessarily "clear" (i.e. not FEC encoded).

Both the FEC encoding process and the data interleave process is accomplished in a single software program. Due to the data doubling effect of the rate 1/2 encoding, the final transmit data file is about 1785.6 MB (2*892.8 MB) in size. The actual transmitted data stream has a format as illustrated in Figure A3-3 and is generated by accessing/reading this transmit file through an 8.128 Mbs serial controller using an ATT DSP32C VME " Surfboard".

A3.3 SIGNAL DISTRIBUTION

The studio signal distribution path from CD Radio's office in Washington DC NW, uses a Ku band 5.6M uplink satellite antenna dish, an SBS6 satellite and the mobile VSAT terminals in the test vehicle used along the Virginia drive path or range. As the transmit interleaving and FEC encoding is all done in non-real time in software on the Sun workstation, the transmit uplink requirements are relatively simple, namely a high speed (8.192 Mbs) serial controller, a standard OQPSK modulator at the

CD Radio
Encoded TDM Format with Rate 1/2 FEC and Interleaving Frame control

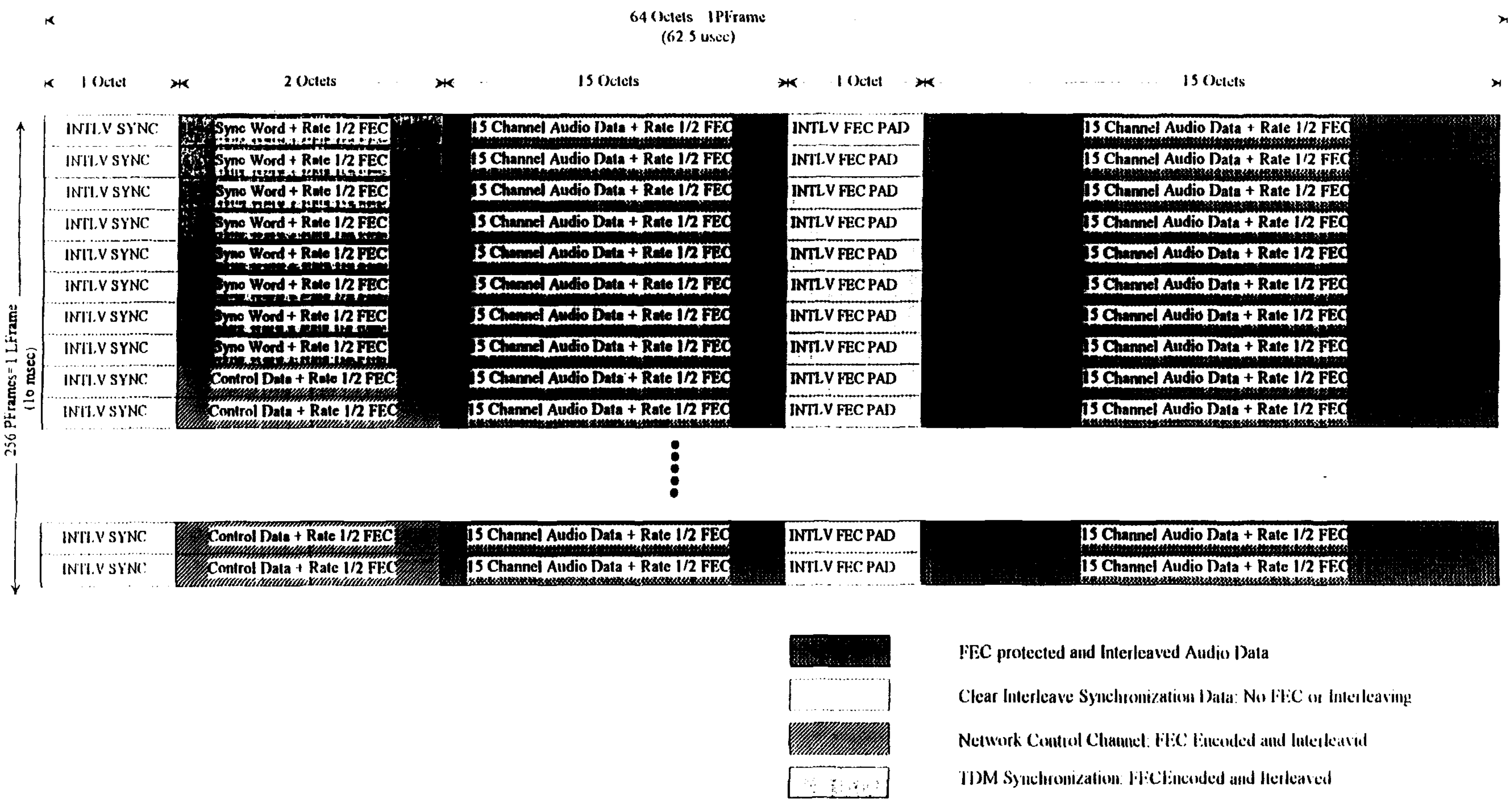


Figure A3-3 Network Control Channel

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DEMONSTRATION STUDIO EQUIPMENT LAYOUT

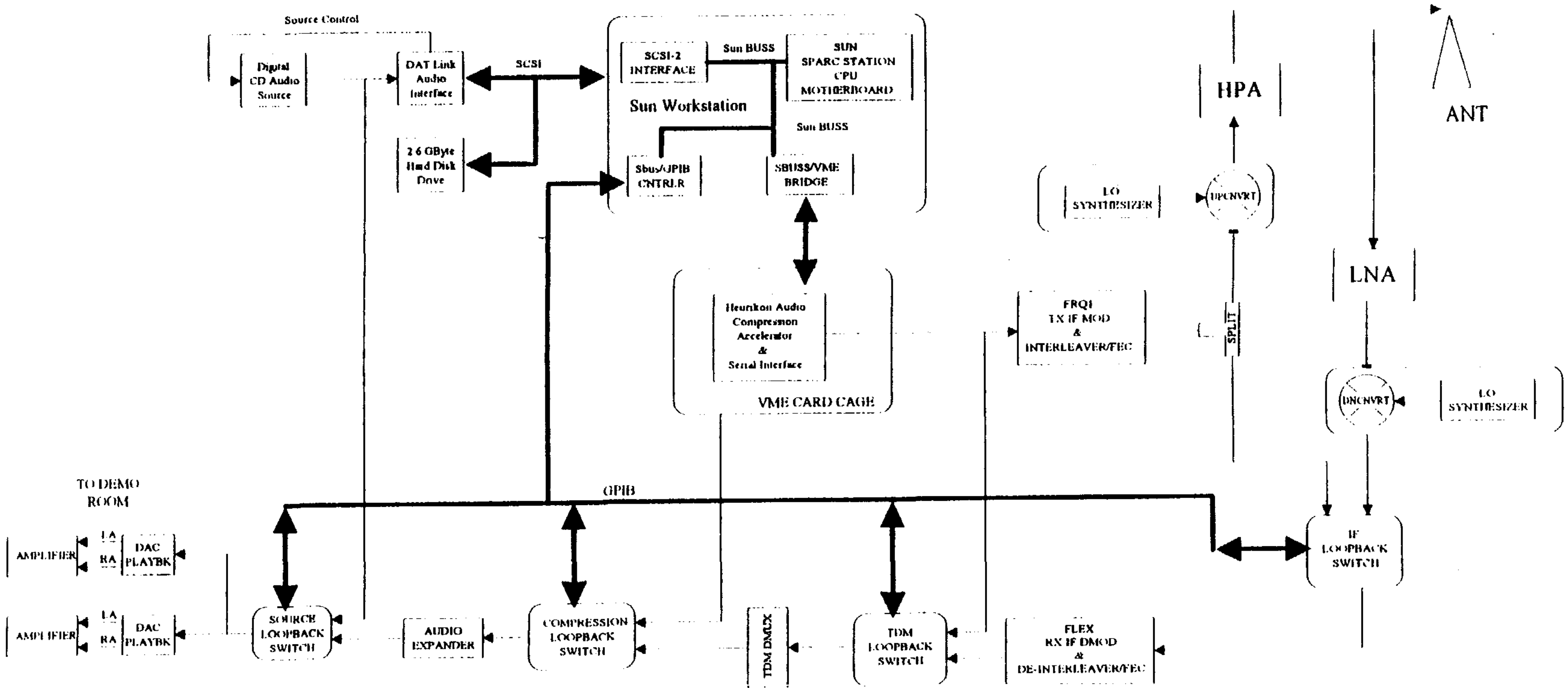

Figure A3-4 Studio Equipment - Block Diagram

CD RADIO INC.

required symbol rate (4.096 Ms/s), a 70 MHz IF frequency, a Ku band upconverter and TWT HPA to drive the 5.6M uplink antenna. To facilitate loopback and benchtop testing the studio transmit site was equipped with loopbacks under GPIB control. Figure A3-4 illustrates the studio equipment configuration with the GPIB controlled loopbacks at baseband, IF and RF.

A3.3 ROOFTOP TRANSMISSION

The Roof-Top Transponder receives the wideband digital signal at Ku-Band from the satellite and down converts the signal to a 300 MHz IF frequency. At IF the signal is bandpass filtered to select only the CD Radio carrier. The signal is then up converted to S-band, amplified to the appropriate power level, and transmitted via an omni-directional (in azimuth) antenna.

A block diagram is provided in Figure A3-5. This diagram identifies each of the major components in the signal path, as well as the approximate gain or loss of each component. At selected points on the diagram, design values are indicated for level of the desired carrier (dBm), estimated level of the composite signal (dBm), frequency band of interest (MHz), and carrier to noise density (dB-Hz). A link budget for the signal distribution equipment is contained in Table A3-1

The Ku-Band signal is received from the satellite via a conventional 1.8 meter parabolic antenna with prime focus, receive-only feed. The antenna is pointed at the correct satellite using a non-penetrating polar mount. The received signal is then amplified and converted to L-Band by an LNB mounted directly at the feed horn. The LNB is characterized by high stability, low phase noise, a minimum gain of 55 dB and a maximum Noise Figure of 1.8 dB. The resulting L-Band signal is then amplified again with an in-line L-Band amplifier and carried to the Transponder enclosure.

The L-Band signal input is down converted from L-Band to 300 MHz. A low phase noise synthesizer produces a local oscillator (LO) signal in the range 1250 to 1750 MHz in 500 kHz steps. This LO is used to high side

CD RADIO INC.

Figure A3-5 Rooftop Transponder - Block Diagram

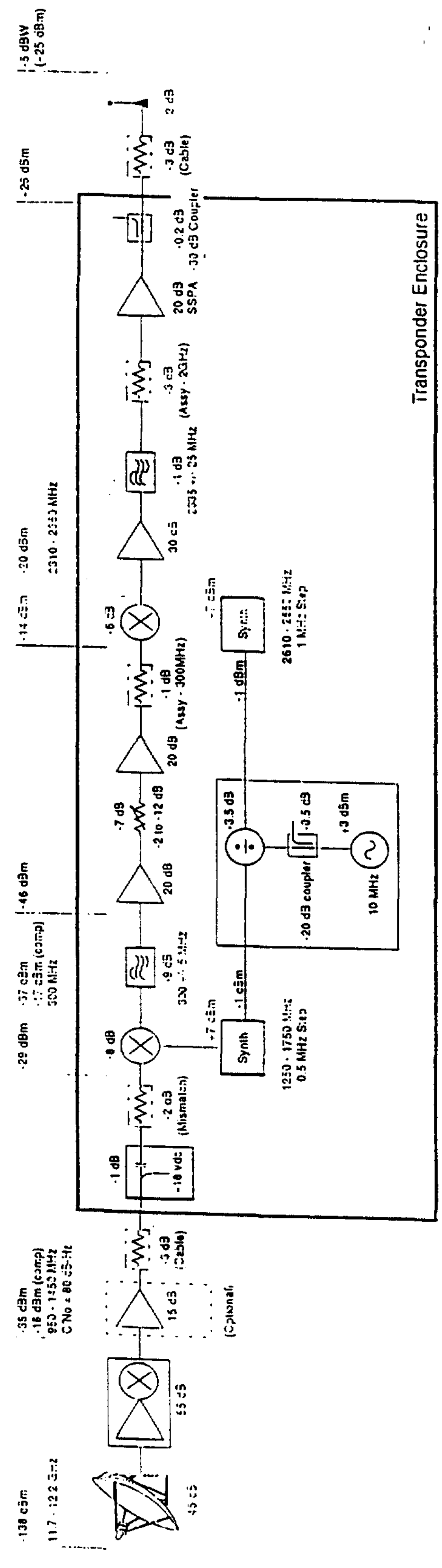

Table A3-1 Link Budget - Ku-Band Satellite Up Link

EARTH STATION TO SATELLITE AT Ku-BAND		PAGE 1 OF 3	
CD RADIO DEMONSTRATION LINK BUDGET		22-Apr-93	
TRANSMIT POWER			
	Transmit Power (watts)	100.0 W	
	Transmit Power (decibels)	20.0 dBW	
	Cable Losses	-1.0 dB	
	Pointing Error Loss	-0.9 dB	
	Antenna Gain	56.2 dBi	
	Carrier EIRP	74.3 dBW	
SYSTEM PERFORMANCE			
	Propagation Loss	-207.0 dB	
	Range Loss	-163.0 dB	
	Received Power Flux Density	-88.7 dBW/m2	
	Satellite Transponder Saturated Flux Density	-91.0 dBW/m2	
	Required Flux Density	-96.2 dBW/m2	
	Up-Link Margin	7.5 dB	
	Channel Encoding Rate	128 Kbps	
	Number of Channels	31	
	Data Rate	3968 Kbps	
	Modulation	OQPSK	
	Error Correction Coding	Rate 1/2	
	Carrier Bandwidth	5158.4 KHz	
	Received Power	-140.2 dBW	
	Receiver G/T (GSTAR III)	6.4 dB/K	
	Carrier to Noise Density	94.8 dBHz	
	Carrier to Noise	27.6 dB	
TRANSMIT CHAIN		NOMINAL	MAXIMUM
	XMTR Power (Antenna Flange)	11.5 dBW	13.0 dBW
	Wave Guide Loss	-1.0 dB	-1.0 dB
	XMTR Power (Monitor Port)	-26.5 dBm	-25.0 dBm
	XMTR Power	12.5 dBW	14.0 dBW
		17.7 Watts	25.1 Watts
	XMTR Gain	40.0 dB	40.0 dB
	Wave Guide Loss	-5.0 dB	-5.0 dB
	Ku-Band Pre-Amp Gain	0.0 dB	0.0 dB
	Up-Converter Output Power (Monitor Port)	-12.5 dBm	-11.0 dBm
	Up-Converter Output Power	7.5 dBm	9.0 dBm
	Up-Converter Attenuator	-10.0 dB	-10.0 dB
	Up-Converter Gain	38.0 dB	38.0 dB
	Cable Loss	-6.7 dB	-6.7 dB
	VSAT Terminal	-13.8 dBm	-12.3 dBm

Table A3-1 Link Budget - Ku-Band Satellite Down Link

SATELLITE TO ROOF TOP AT Ku-BAND	PAGE 2 OF 3
CD RADIO DEMONSTRATION LINK BUDGET	22-Apr-93
TRANSMIT POWER	
Transponder Power (SBS6)	50.4 dBW
Percent of XPNDR Power	30.0%
Carrier EIRP	45.2 dBW
Radiated Power Flux Density	14.1 dBW/4KHz
RECEIVED POWER	
Propagation Loss	-205.0 dB
Antenna Gain (2.0M)	45.0 dBi-
Adjacent Satellite Interference Noise Temperature	50.0 K
Clear Sky Noise	50.0 K
Antenna Noise Temperature	80.0 K
LNA Noise Temperature	80.0 K
System Noise Temperature	260.0 K
Receive Noise Temperature (dB above 1 deg)	24.1 dB
Boltzmann's Constant	-228.6 dBW/Hz/K
Received Power	-159.8 dBW
Receiver Bandwidth	5158.4 KHz
SYSTEM PERFORMANCE	
Effective Receive G/T	20.9 dB
Carrier to Noise Density - Down Link	89.6 dBHz
Carrier to Noise Density - Up Link	94.8 dBHz
Carrier to Noise Density - Satellite Link	88.5 dBHz
Carrier to Noise	21.3 dB
Required Eb/No (10-5 BER RATE 1/2 FEC)	5 dB

Table A3-1 Link Budget - S-band to Mobile Vehicle

ROOF-TOP TO VEHICLE LINK AT 2310 GHz	PAGE 3 OF 3	
CD RADIO DEMONSTRATION LINK BUDGET	22-Apr-93	
TRANSMIT POWER		
Transponder Power	1.00 W	
Transponder Power	0.00 dBW	
Cable Losses	-3.00 dB	
Antenna Gain	0.00 dB	
Carrier EIRP	-3.00 dBW	
RECEIVED POWER		
Path Loss - 2 miles	-112.0 dB	
Antenna Gain	1.0 dB	
Cable Loss	-0.5 dB	
Channel Encoding Rate	128 Kbps	
Number of Channels	31	
Data Rate	3968 Kbps	
Modulation	OQPSK	
Error Correction Coding	Rate 1/2	
Carrier Bandwidth	5158.4 KHz	
Received Carrier Power	-114.5 dBW	
SYSTEM NOISE POWER		
Receiver Noise Figure	1.8 dB	5
Receiver Temperature	148.9 K	
Clear Sky Noise	10.0 K	
Antenna Noise Temperature	60.0 K	
Receive Noise Temperature (dB above 1 deg)	23.4 dB	
Receiver Noise Bandwidth	5158 KHz	
Boltzmann's Constant	-228.6 dBW/Hz/K	
Receiver Noise Power	-138.1 dBW	
SYSTEM PERFORMANCE		
Carrier to Noise Density - Roof Top Link	90.7 dBHz	
Carrier to Noise Density - Satellite Link	88.5 dBHz	
Carrier to Noise Density - Total	86.4 dBHz	
Carrier to Noise Ratio - Total	19.3 dB	
Eb/No	19.3 dB	
Required Eb/No (10-5 BER RATE 1/2 FEC)	5.0 dB	
Link Margin	14.3 dB	

mix with the incoming L-Band signal, resulting in a spectral inversion of the signal. The goal of this stage is to translate the specific frequency, at which the received wideband digital carrier is centered, to a fixed IF of 300 MHz. Thus, this synthesizer permits selection of the receive Ku-Band carrier channel.

Following down conversion, the 300 Mhz signal is narrow-band filtered in order to eliminate unwanted signals found on the satellite, as well as harmonic images produced by the mixer. This filter also has the characteristic that it has low group delay across the null-to-null bandwidth of the wideband digital carrier. This ensures that the digital signal experiences minor degradation due to distortion introduced by the filtering process, while guaranteeing that unwanted signals are not propagated through the system.

The filtered IF signal then passes through a series of gain and attenuation stages which are used to amplify the signal, as well as provide a means to adjust the overall gain of the Transponder, with the net effect of allowing the level of the S-band signal to be set on an installation-by-installation basis.

Following the filtering and level adjustment stages, the 300 MHz selected signal is up converted to S-band (2310 to 2360 MHz). As with the down conversion stage, a low phase noise synthesizer produces a local oscillator (LO) signal in the range 2610 to 2660 MHz in 1.0 MHz steps. This LO is used to high side mix with the 300 MHz IF signal, resulting in a second spectral inversion. This second inversion ensures that no spectral inversion occurs within the Rooftop Transponder from input to output. Also, as with the down conversion stage, the goal is to translate the fixed frequency signal to the required S-band center frequency. Thus, this synthesizer permits selection of the transmit S-band carrier channel.

The frequency synthesizers which produce the LOs for down and up conversions are phase locked to a single, high stability, low phase noise crystal oscillator operating at a frequency of 10.0 MHz. This oscillator is mounted on the PC board located on the bottom plate of the enclosure.

Following up conversion of the carrier to the desired S-band center frequency, the signal is passed through an intermediate gain stage, filtered to eliminate mixer harmonics, and finally amplified by a solid state power amplifier (SSPA) to achieve the desired transmit level. The output power may be measured by means of a calibrated 30 dB coupler placed immediately before the bulkhead of the enclosure. This permits monitoring of the transmitted signal while it is active.

Finally, the transmitted high power signal exiting from the enclosure is sent via low loss cable to the S-band antenna which is mounted at the top of a 20 foot pole. The circularly-polarized antenna has a pattern which is omni-directional in the azimuth plane, has a beam center gain of approximately 2 dB, and a 3 dB elevation beamwidth of approximately 55 degrees.

A3.4 AUTOMOBILE RECEIVING ANTENNA

A major technical effort by CD Radio extending over the last few years concerned the receiving antenna on the automobile operating in the 2310-2360 Mhz frequency band. It was desired that an antenna be developed which could be used with both after-market installations on already delivered cars and dealer delivered cars with integrated radio-antenna sets. The latter installation was particularly technically challenging since it was desired that the antenna be invisible so both automobile aesthetics was unaffected and theft aspects eliminated.

A developmental effort was initiated which produced an antennal meeting these requirements and the satellite system transmission performance requirements following:

Gain:	3dBi over the 20° - 60° elevation angle range for all azimuth angles
Gain Ripple:	+/-1 dB between + 1 and + 3 dBi
Bandwidth:	+/-25 Mhz centered at 2335 Mhz.

Polarization: Left hand circularly polarized (LHCP) with axial ratio sufficient to provide 20 dB isolation from cross polarized transmissions.

The antenna was developed for CD Radio by Seavey Engineering and tested. The basic antenna (Figure A3-6) is a 1.88" diameter microstrip antenna operating in the TE20 mode. The ceramic disk substrate consists of 96% Coors alumina. It is covered entirely on one side and 1.58" in diameter on the other by a 0.002" thick coating of silver palladium. The side with 1.58" diameter of metalization is referred to as the circuit or radiating side. When mounted in the car roof it is covered with a layer of autobody filler. The disk also consists of a female SMA connector located 0.375" from the center of the disk. A small notch has been removed from the edge of the circuit side 0.225" away from the center of the disk in line with the connector to achieve circular polarization.

The antenna would be typically mounted in a 2 inch diameter depression in the center top of the automobile roof shown in Figure A3-7. A hole in the depression allows connection of the antenna to the radio frequency pre-amplifier. After covering the sides and top of the antenna in the depression with autobody filler, the roof is repainted to create antenna invisibility. Ground planes were constructed for antenna testing which were flat and which were curved with the aforementioned depression so the effect of the latter on performance could be determined.

Detailed test data were taken on radiation patterns using the set up shown in Figure A3-7. The antenna under test (AUT) was centered over an elevation-over-azimuth antenna test pedestal located at one end of a 30-foot anechoic test chamber. An LHCP 1-4 GHz spiral source antenna was connected to a CW Signal Generator located 15 feet from the AUT. The received signal was recorded using a Scientific Atlanta test instrumentation receiver and rectangular chart recorder calibrated by linearity tests.

To measure gain, a rotating Standard Gain Horn (SGT)- Model #9142-800 was used as a source antenna. A second antenna - SGT Model #SGT 1.70,

Figure A3-6 Automobile Receiving Antenna

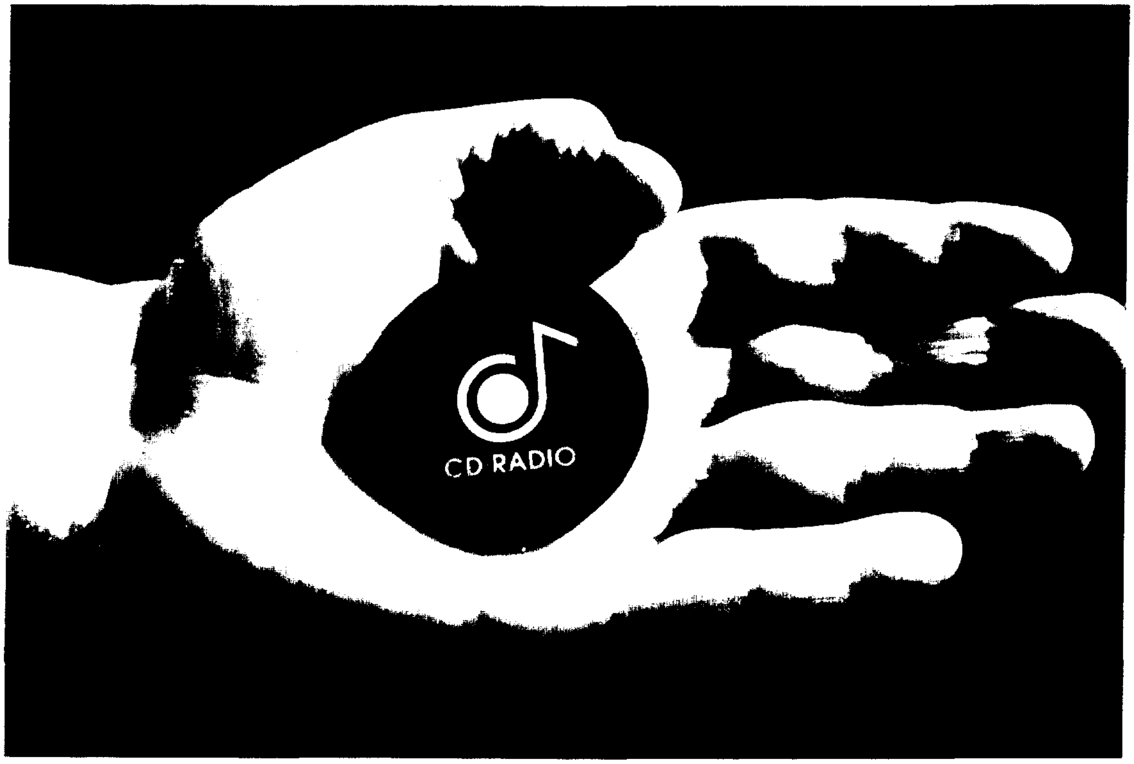

Figure A3-7 Automobile Receiving Antenna, Mounted

CD RADIO SYSTEM DEMONSTRATION

MUSIC PROGRAMMING

May 8, 1993

SYMPHONIC- 1   32:47

1089 (32:47) 1,2   "Symphony No. 3 in E flat "Eroica", Beethoven, Mariner (Philips 410 044 2)

CHAMBER MUSIC- 2   31:04

1087 (13:32) 1   "Quintet in A Major Op 114 "Trout", Schubert, Smetena Quartet (Denon 38C37 7239)

1088 (17:32) 1,2   "String Quartet No. 17 in B-flat Maj," Mozart, Kocian Quartet (Denon 33C37 7538)

OPERA- 3   31:31

1054 (11:50) 5   "Deh! con te li prendi ...Mira, o Norma," Norma, Bellini, **Great Operatic Duets,** (London 421 3134-2)

1055 (4:36) 1   "Va, Pensiero," Nabuco, Verdi, **Famous Opera Choruses** (London 421 176-2)

1055 (2:38) 2   "Vedi! Le Fosche," Il Trovatore, Verdi, **Famous Opera Choruses** (London 421 176-2)

1055 (3:56) 8   "Pilgrim's Chorus," Tanhauser, Wagner, **Famous Opera Choruses** (London 421 176 2)

1056 (3:28) 5   "M'appari tutt'amor," Martha, Flotow, **Tutto Pavarotti** (London 425 681 2)

1056 (4:29) 16   "Che gelida manina" La Boheme, Puccini, **Tutto Pavarotti** (London 425 681 2)

TODAY'S COUNTRY- 4 27:20

1015 (4:12) 4 "Walkaway Joe", Trisha Yearwood, **Hearts In Armor** (MCA 10641)

1016 (2:35) 1 "It's A Little Too Late", Tanya Tucker, **Can't Run From Yourself** (Liberty 98987)

1017 (3:41) 5 "When My Ship Comes In", Clint Black, **The Hard Way** (RCA 66003)

1018 (3:08) 2 "Drive South", Suzy Bogguss, **Voices In The Wind** (Liberty 98585)

1019 (3:16) 4 "Let Go Of The Stone", John Anderson, **Seminole Wind** (BNA 61029)

1130 (3:25) 3 "She's Not Cryin' Anymore", Billy Ray Cyrus, **Some Gave All** (Mercury 510635)

1137 (2:43) 3 "What Part Of No", Lorrie Morgan, **Watch Me** (BNA 66047)

1096 (3:33) 2 "Can I Trust You With My Heart", Travis Tritt, **T-R-O-U-B-L-E** (Warner Bros. 45048)

TRADITIONAL COUNTRY- 5 24:07

1020 (2:56) 5 "D-I-V-O-R-C-E", Tammy Wynette, **Greatest Hits** (Epic 26486)

1021 (2:34) 1 "She Thinks I Still Care", George Jones, **Greatest Country Hits** (Curb D2-77369)

1022 (2:26) 1 "Oh, Lonesome Me", Don Gibson, **Country Spotlight** (Dominion 3082-2)

1023 (2:48) 1 "Folsom Prison Blues", Johnny Cash, **The Sun Years** (Rhino R2 70950)

1024 (2:53) 1 "Okie From Muskogee", Merle Haggard, **The Best Of Merle Haggard** (Capitol C2 91254)